Hydrogeologic Framework of the Floridan Aquifer System in Florida and in Parts of Georgia, Alabama, and South Carolina

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REGIONAL AQUIFER-SYSTEM ANALYSIS

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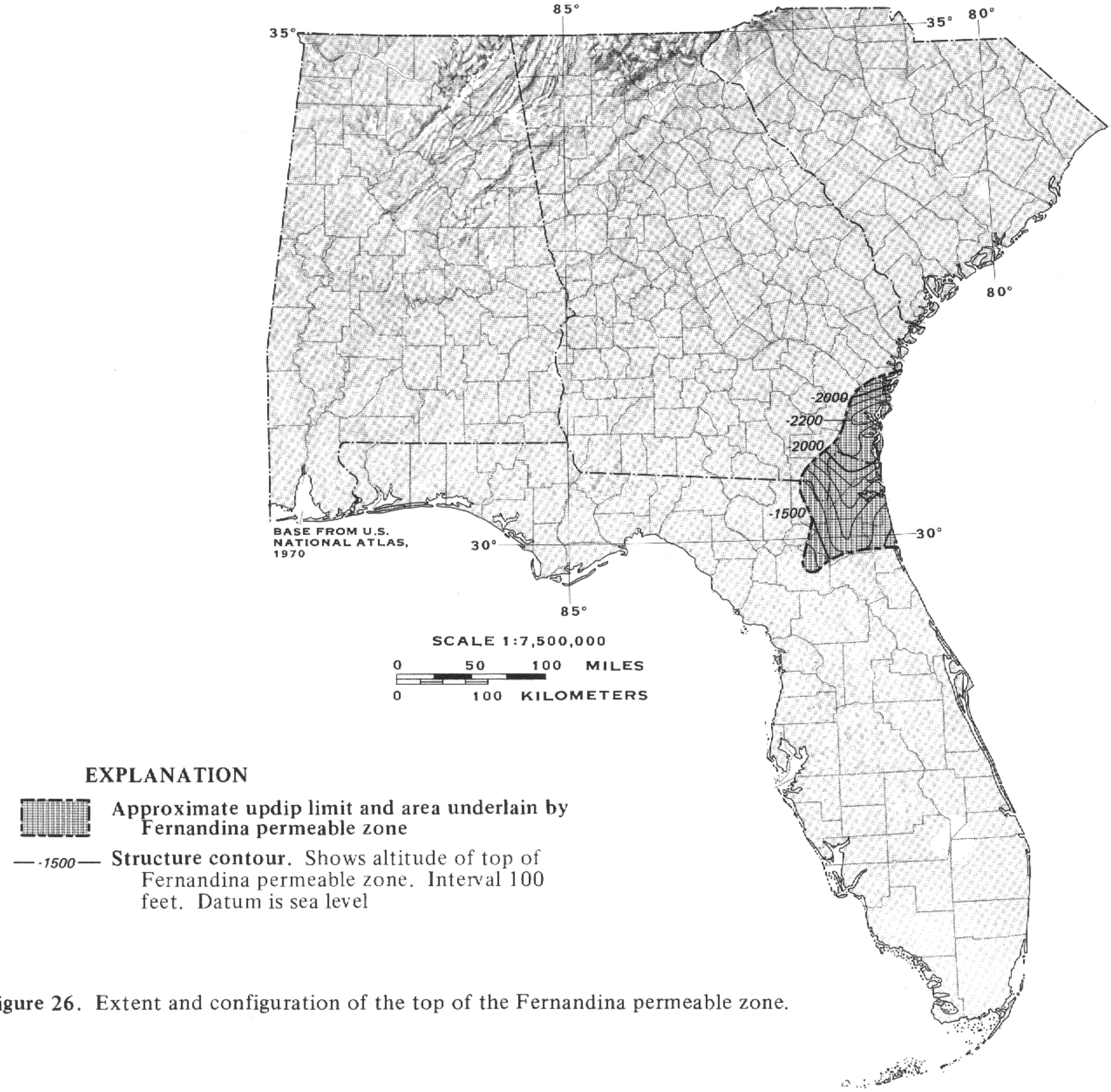

Figure 26. Extent and configuration of the top of the Fernandina permeable zone.

system's regional flow network, however. Although the Fernandina zone is locally cavernous, it is in no way connected with or related to south Florida's Boulder Zone. The Fernandina permeable zone is included as a subunit of the Lower Floridan aquifer (fig. 8).

LOWER CONFINING UNIT

The rocks that comprise the Floridan aquifer system's lower confining unit are generally of two types: either glauconitic, calcareous, argillaceous to arenaceous strata that range in age from late Eocene to late Paleocene or massively bedded anhydrite that usually occurs in the lower two-thirds of rocks of Paleocene age. Locally, in the Mobile Graben and just to the northwest of it in western Alabama, the Lower Floridan aquifer is not present, and the Bucatunna Formation that comprises middle confining unit V elsewhere forms the base of the aquifer system. The permeability of the rocks comprising the aquifer system's base is everywhere much less than that of the carbonate rocks that lie above them. Like the top of the aquifer system, its base is defined in terms of a permeability contrast and does not conform to the same geologic horizon or rock type everywhere. The altitude and configuration of the base of the aquifer system (top of its lower confining unit) as shown on plate 33, modified from a map by Miller (1982c), thus represent a composite surface that crosses formation and time boundaries. The base of the Floridan aquifer system does not crop out, and the areal extent and lithologic character of the different units delineated on plate 33 were determined solely from well control. Low-permeability clastic rocks that are the stratigraphic equivalents of the aquifer system's base do, in fact, crop out updip from the limit of the aquifer system. Where the aquifer system itself is not present, however, it is meaningless to map these low-permeability rocks as the system's base. The altitude of the base of the aquifer system may differ locally from that shown, particularly in areas of sparse well control. Although the different units shown in updip areas extend north and west of the line that marks the aquifer's approximate updip extent, they have not been mapped past the limit of the aquifer. It is important to stress that the contours shown on plate 33 generally do not represent the top of a particular time-stratigraphic unit; rather, they show the top of a permeability contrast that usually occurs within such a unit. Below the altitudes shown, there is no high-permeability carbonate rock. The different time-stratigraphic units that comprise the aquifer system's base, as shown on plate 33, are described in order below, from youngest to oldest. In general, the base of the aquifer system is marked by progressively older rocks in a downdip direction because depositional environments become progressively more marine and thereby more favorable for the accumulation of a thicker sequence of permeable limestone in a seaward direction.

ROCKS OF LATE EOCENE AGE

In western panhandle Florida and southern Alabama, the Floridan aquifer system's lower confining unit consists of interbedded glauconitic, calcareous sand and sandy clay of late Eocene (Jacksonian) age. These rocks lie immediately under the Ocala Limestone. Although detailed correlation has not been done between these calcareous clastic rocks and outcropping upper Eocene rocks, they are thought to be equivalent to the Moodys Branch Formation of western Alabama. In Geneva and Houston Counties in southeastern Alabama (pl. 33), the small area of upper Eocene rocks that comprises the base of the aquifer is also thought to be equivalent to the Moodys Branch. The upper Eocene strata in this small area are glauconitic, calcareous clastic rocks, lithologically similar to the outcropping Moodys Branch. In the northeastern part of the Georgia coastal plain, upper Eocene rocks that consist of fossiliferous, slightly sandy and glauconitic, calcareous clay mark the base of the aquifer system. These rocks are equivalent to the Eocene part of the Cooper Formation (formerly called the Cooper Marl), a low-permeability unit that is in part of late Eocene and in part of Oligocene age (pl. 2). In south-central Georgia, a small, roughly oval patch of upper Eocene rocks makes up the base of the aquifer system (pl. 33). These strata are adjacent to and just down the hydraulic gradient from a series of small faults that bound narrow grabens. The rocks, which are part of the Ocala Limestone, consist primarily of bryozoan particles and whole to broken large Foraminifera loosely bound by a micrite matrix. Here, however, gypsum has filled most of the pore space in the normally highly permeable Ocala. The gypsum has not been dissolved, probably because movement along the faults has downdropped low-permeability clastic rocks that fill the grabens opposite high-permeability limestone to the northwest and thereby created a damming effect on ground-water flow within the Floridan aquifer system. The restricted flow southeast of the faulted area has not been sufficient to remove the pore-filling gypsum from the Ocala. These low-permeability Ocala beds grade downward into glauconitic clastic rocks of middle Eocene age, with no permeable limestone between the clastic and gypsum-rich strata.

ROCKS OF MIDDLE EOCENE AGE

Adjacent to the updip limit of the Floridan aquifer system in southwestern Georgia and much of southeastern Alabama and for a considerable distance downdip of these areas (pl. 33), the aquifer system's lower confining unit consists of fine-grained, calcareous, glauconitic sand interbedded with gray to greenish-gray clay and clayey sand. These clastic strata are of middle Eocene (Claibornian) age and are thought to be equivalent to the outcropping Lisbon Formation (upper part of the middle Eocene). Farther downdip, as the amount of permeable limestone in the Tertiary section increases, the aquifer system thickens rapidly, and its base becomes progressively lower to the southeast with respect to both altitude and stratigraphic position. In a narrow, irregular, northeast-trending strip across the central Georgia coastal plain (pl. 33), the clastic rocks that are Lisbon equivalents grade by facies change into permeable limestone. Here the aquifer system's lower confining unit consists of highly glauconitic, fine-grained, greenish-gray sand interbedded with green to brown clay or clayey sand, all equivalent to the Tallahatta Formation of outcrop (lower part of the middle Eocene). In the central and east-central parts of panhandle Florida, the amount of permeable limestone in the aquifer system thickens toward the Gulf of Mexico, and the system's base becomes stratigraphically lower, as it does in Georgia. In the panhandle area, however, there is no lithologic or paleontologic difference between the upper and lower parts of the middle Eocene section. The glauconitic, calcareous clastic rocks that mark the base of the aquifer system are accordingly mapped on plate 33 as equivalent to the Lisbon Formation; the Tallahatta equivalent cannot be distinguished. In the area of southwestern South Carolina and northeastern Georgia that is adjacent to the Savannah River (pl. 33), the aquifer system's lower confining unit is comprised of highly sandy, greenish-gray, calcareous clay interbedded with soft, sandy to argillaceous limestone and fine-grained calcareous sand. These rocks are thought to be equivalent to parts of the Santee Limestone of South Carolina. The Lisbon and Tallahatta equivalents together grade laterally northeastward into the Santee by facies change.

ROCKS OF EARLY EOCENE AGE

In a narrow band in eastern panhandle Florida and a slightly wider strip in east-central Georgia, clastic rocks of early Eocene (late Sabinian) age form the Floridan aquifer system's lower confining unit (pl. 33). These rocks, which consist of highly glauconitic, silty, often micaceous, fine-grained sand interbedded with brown lignitic clay, are all of low permeability and are thought to represent in part the equivalents of the Hatchitigbee and Tuscahoma Formations that crop out in Alabama. Like the middle Eocene strata in east-central panhandle Florida, they cannot be differentiated into discrete formations in the subsurface and accordingly are mapped on plate 33 as "undifferentiated rocks of early Eocene age." Finely-crystalline, dark-gray, gypsiferous limestone interfingers with these clastic rocks locally, particularly adjacent to places where the Oldsmar Formation forms the aquifer system's base. The Oldsmar represents a carbonate-bank facies of the undifferentiated lower Eocene clastic rocks. The Oldsmar beds that form the aquifer system's lower confining unit in southcentral Georgia and contiguous parts of northern Florida (pl. 33) are glauconitic, micritic to finely crystalline, gypsiferous, cream, brown, and dark-gray limestone interbedded with dark-brown gypsiferous dolomite. In most of southwestern South Carolina (pl. 33), the base of the aquifer system consists of interbedded gray to black clay, red to brown sandy clay, and fine-grained, white, calcareous sand and clayey sand, all of which are equivalent to the upper part of the Black Mingo Formation.

ROCKS OF PALEOCENE AGE

Throughout most of Franklin County and in southern Gulf and Liberty Counties in Florida's eastern panhandle (pl. 33), the base of the Floridan aquifer system consists of hard, cherty, sandy, finely crystalline limestone thickly interbedded with massive brown to black clay. These rocks are of Paleocene age but have no exact corollary in the outcropping Paleocene rocks of either Georgia or Alabama. Their overall lithology resembles that of the Clayton Formation more closely than that of any other described Paleocene unit, and they are accordingly mapped as questionably equivalent to that formation. Eastward, these rocks grade into an interbedded carbonate-evaporite sequence that is part of the Cedar Keys Formation. Cedar Keys rocks, as plate 33 shows, make up the aquifer system's lower confining unit over practically all of peninsular Florida and over a small area in southeastern Georgia. The Cedar Keys consists mostly of thick-bedded dolomite and dolomitic limestone; massive anhydrite beds occur in the lower two-thirds of the formation. These areally extensive, low-permeability evaporites form a very effective confining bed at the aquifer system's base. The permeable dolomite and dolomitic limestone in the upper part of the Cedar Keys are included in the Floridan aquifer system, however. Accordingly, the drastic permeability decrease that marks the aquifer system's base occurs within the Cedar Keys, not at the formation's top. Anhydrite beds occur locally in younger rocks, especially in the lower Eocene Oldsmar Formation and less commonly in the lower part of rocks of middle Eocene age. The evaporite beds do not make up a regional confining unit in any horizon younger than the Paleocene, however. In the central part of western peninsular Florida, a middle Eocene gypsiferous dolomite unit has previously been mapped as the base of the aquifer system (Wolansky and others, 1979). Although this low-permeability dolomite does constitute an effective confining unit (middle confining unit II of this report), deep well data show that it is underlain by permeable limestone considered in this report to be part of the Lower Floridan aquifer. Accordingly, anhydrite beds of the Cedar Keys Formation, which in turn lie beneath the lower major permeable zone, make up the aquifer system's base here, as they do elsewhere in the Florida peninsula.

ROCKS OF LATE CRETACEOUS AGE

The Floridan aquifer system is very thick in the Brunswick, Ga., area. Test wells in southern Glynn County, Ga., show that rocks of Oligocene age through the upper part of rocks of Late Cretaceous age are part of the aquifer system there. The base of the system lies several hundred feet below the top of the Late Cretaceous and consists of soft, friable limestone of probable Taylor age (pl. 33). These rocks, which lie entirely in the subsurface, are at present unnamed in both Florida and Georgia. The permeable Cretaceous limestone that overlies the rocks of Taylor age is part of the Lawson Limestone of Navarro age.

CONFIGURATION OF SURFACE

Although the top of the lower confining unit represents a composite of the tops of several low-permeability horizons of different ages and different rock types, some of the large-scale features contoured on plate 33 reflect major structural elements in the eastern Gulf Coast. The east-trending low area centered near Brunswick, Ga., is part of the Southeast Georgia embayment; the negative area in Franklin and Gulf Counties, Fla., represents the Southwest Georgia or Apalachicola embayment; and the low area centered in Lee and Hendry Counties, Fla., is part of the South Florida basin. The steep, steady gulfward slope of the aquifer system's base in western panhandle Florida reflects the influence of the Gulf Coast geosyncline.

The axis of the positive area in northwestern peninsular Florida lies in an intermediate position between the axis of the Peninsular arch and the axis of the "Ocala uplift." This high area probably represents the approximate location of the Peninsular arch or is related to it, even though the axes of the two features do not exactly coincide.

In the broad area in peninsular Florida where anhydrite beds of the Cedar Keys Formation form the base of the aquifer system (pl. 33), the altitude of the highest anhydrite bed has been plotted and then contoured as if the evaporites were everywhere continuous. Actually, they are not. The anhydrite beds probably formed in tidal flat or sabkha environments that were of local extent (P. A. Thayer, personal commun., 1982) and, after burial, now occur as isolated discontinuous lenses that "float" in a mass of carbonate rocks. The lenses are confined, however, to a zone within the middle to lower third of the Cedar Keys, and it is the surface of this evaporite-rich zone that is contoured. Thus, the small, low- to moderate-relief (100 - 300 ft) positive and negative features shown on plate 33 in southern peninsular Florida, rather than being local structural features, represent local evaporite beds that occur at altitudes higher or lower than those of the main body of the Cedar Keys anhydrite-rich zone.

The faults shown in central Georgia on plate 33 are those that bound the series of small grabens called the Gulf Trough. The faults cut the low-permeability rocks that comprise the base of the aquifer system and displace them as shown. Because of the lack of deep well control in and adjacent to the Gulf Trough, the depth to which these faults penetrate is not known. Their geometry, however, indicates that they probably die out at a relatively shallow depth. The faults in southwestern Alabama, which also bound a series of grabens, also cut the base of the aquifer system. Unlike the faults that bound the Gulf Trough, the Alabama faults are known to extend to great depths (Copeland, 1968; Moore, 1971). To the south and west of the Alabama faults, the Floridan aquifer system is very thin and effectively isolated from the main body of limestone because movement along the faults has downdropped relatively impermeable beds opposite the permeable limestone of the aquifer system.

REGIONAL VARIATIONS IN PERMEABILITY

The rocks that make up the Floridan aquifer system are a series of platform carbonate beds that were laid down in warm, shallow water in an environment similar to that of the modern Bahama Banks. The original texture of the limestone ranged from micritic to biosparruditic (textural terms from Folk (1959)) and, like modern carbonates, varied considerably over short lateral distances, depending upon the exact depositional environment at a given place. Slight differences in the depth, temperature, and salinity of ocean waters or in current strength and distribution affect the types and numbers of calcium carbonate-fixing organisms that are present as well as the amount of micrite and the percentage and size of limestone pellets that can accumulate. As the carbonate sediment becomes consolidated, these organic and textural factors determine the primary texture of the limestone formed, which in turn determines the primary porosity and permeability of the rock. For example, the Ocala Limestone, which is part of the Upper Floridan aquifer, was deposited in shallow, warm, clear water and consists in many places of a coquina of bryozoan fragments and large Foraminifera loosely cemented with sparry calcite or a small amount of micrite. The permeability of the Ocala is high nearly everywhere. By contrast, gypsiferous dolomite of middle Eocene age (middle confining unit II) was deposited largely in a series of sabkhas or tidal flats, and has a very low permeability.

Diagenesis subsequent to deposition at any stage of consolidation of the rock can either enhance or decrease limestone permeability. For the Floridan aquifer system, dolomitization has been the chief diagenetic process affecting permeability. Depending upon the original limestone texture, dolomitization can increase or decrease the porosity of the rock. If the original rock is a micrite, it may be recrystallized into a loosely interlocking mosaic of dolomite crystals that is highly porous. On the other hand, if the originally high porosity of a loosely packed, coarsely pelletal limestone is almost completely filled with finely crystalline